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DOI:

[10.1136/bmjopen-2017-020372](https://doi.org/10.1136/bmjopen-2017-020372)

*Document Version*

Publisher's PDF, also known as Version of record

[Link to publication record in King's Research Portal](#)

*Citation for published version (APA):*

Sheehan, K. J., Levy, A. R., Sobolev, B., Guy, P., Tang, M., Kuramoto, L., Sutherland, J. M., Beaupre, L., Morin, S. N., Harvey, E., Bradley, N., & Canadian Collaborative Study on Hip Fractures (2018). Operationalising a conceptual framework for a contiguous hospitalisation episode to study associations between surgical timing and death after first hip fracture: A Canadian observational study. *BMJ Open*, 8(12). <https://doi.org/10.1136/bmjopen-2017-020372>

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# BMJ Open Operationalising a conceptual framework for a contiguous hospitalisation episode to study associations between surgical timing and death after first hip fracture: a Canadian observational study

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**To cite:** Sheehan KJ, Levy AR, Sobolev B, *et al.* Operationalising a conceptual framework for a contiguous hospitalisation episode to study associations between surgical timing and death after first hip fracture: a Canadian observational study. *BMJ Open* 2018;**8**:e020372. doi:10.1136/bmjopen-2017-020372

► Prepublication history for this paper is available online. To view these files, please visit the journal online (<http://dx.doi.org/10.1136/bmjopen-2017-020372>).

Received 30 October 2017  
Revised 5 October 2018  
Accepted 12 October 2018



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## ABSTRACT

**Objective** We describe steps to operationalise a published conceptual framework for a contiguous hospitalisation episode using acute care hospital discharge abstracts. We then quantified the degree of bias induced by a first abstract episode, which does not account for hospital transfers.

**Design** Retrospective observational study.

**Setting** All acute care hospitals in nine Canadian provinces.

**Participants** We retrieved acute hospitalisation discharge abstracts for 189 448 patients aged 65 years and older admitted to acute care with hip fracture between 2003 and 2013.

**Primary and secondary outcome measures** The percentage of patients treated surgically, delayed to surgery (defined as two or more days after admission) and dying, between contiguous hospitalisation episodes and the first abstract episodes of care.

**Results** Using contiguous hospitalisation episodes, 91.6% underwent surgery, 35.7% were delayed two or more days after admission and 6.7% died postoperatively, whereas, using the first abstract only, these percentages were 83.7%, 32.5% and 6.5%, respectively.

**Conclusion** We demonstrate that not accounting for hospital transfers when evaluating the association between surgical timing and death underestimates reporting of the percentage of patients treated surgically and delayed to surgery by 9%, and the percentage who die after surgery by 3%. Researchers must be aware of this potential and avoidable bias as, depending on the purpose of the study, erroneous inferences may be drawn.

## INTRODUCTION

Hip fractures are one of the most devastating events in an older adults' life with 10% of those aged 65 years and older dying in

## Strengths and limitations of this study

- This study includes a large population-based sample of discharge abstracts of all persons hospitalised after hip fracture in nine Canadian provinces over a 10-year period.
- This study describes methods for operationalising a published conceptual model to quantify avoidable bias by accounting for hospital transfers in database studies of persons after hip fracture.
- This study uses population-based percentages to allow researchers to compare the reduction in bias relative to the increase in complexity of data curation when accounting for hospital transfers.
- The extent to which these findings apply to other complex conditions requiring transfer to specialist care centres needs further exploration.

hospital.<sup>1</sup> Surgical repair is almost always indicated and there is compelling evidence indicating that the timelier the surgery after the fracture, the lower the mortality.<sup>2–5</sup> However, the nature of that association remains to be characterised, specifically: whether mortality increases linearly or non-linearly with longer waiting times and whether there is a threshold below which mortality no longer decreases. Routinely collected administrative health data are well suited to answer these questions. However, these sources of data require substantial curating in order to be used for this purpose. There is little documentation about how to construct episodes of care from raw administrative health data.

We published a conceptual framework for constructing care episodes for studying the

effects of surgical timing on outcomes after first hip fracture.<sup>6</sup> We view an episode as all-contiguous hospitalisations for the same patient. The episode begins with the earliest admission to acute care and ends with discharge from acute care. The scope of the services includes transfers between acute care hospitals. Most patients undergo surgical treatment during their care episode, either during initial hospitalisation,<sup>7</sup> or following transfer from where they were initially admitted.<sup>8</sup> On discharge, some patients return to acute care for a related care episode (revision surgery, medical readmission or change in care). Further, up to 10% will return to acute care for an episode of initial hospitalisation for a subsequent hip fracture.<sup>9</sup>

In this study, we describe steps to operationalise this published conceptual framework using acute care hospital discharge abstracts of persons after hip fracture. We also quantify the percentage of patients treated surgically, delayed to surgery (defined as two or more days after admission) and dying, for both contiguous hospitalisation episodes and first abstract episodes of care.

## METHODS

### Data source

The Canadian Institute for Health Information (CIHI) provided all discharge abstracts with diagnostic codes of hip fracture for patients aged 65 years or older, hospitalised

between 1 April 2003 and 31 March 2013 in nine Canadian provinces (excluding Quebec). We use data elements including admission, procedure and discharge date, and diagnosis codes, and discharge disposition in the construction of care episodes. The University of British Columbia Behavioral Research Ethics Board approved this study.

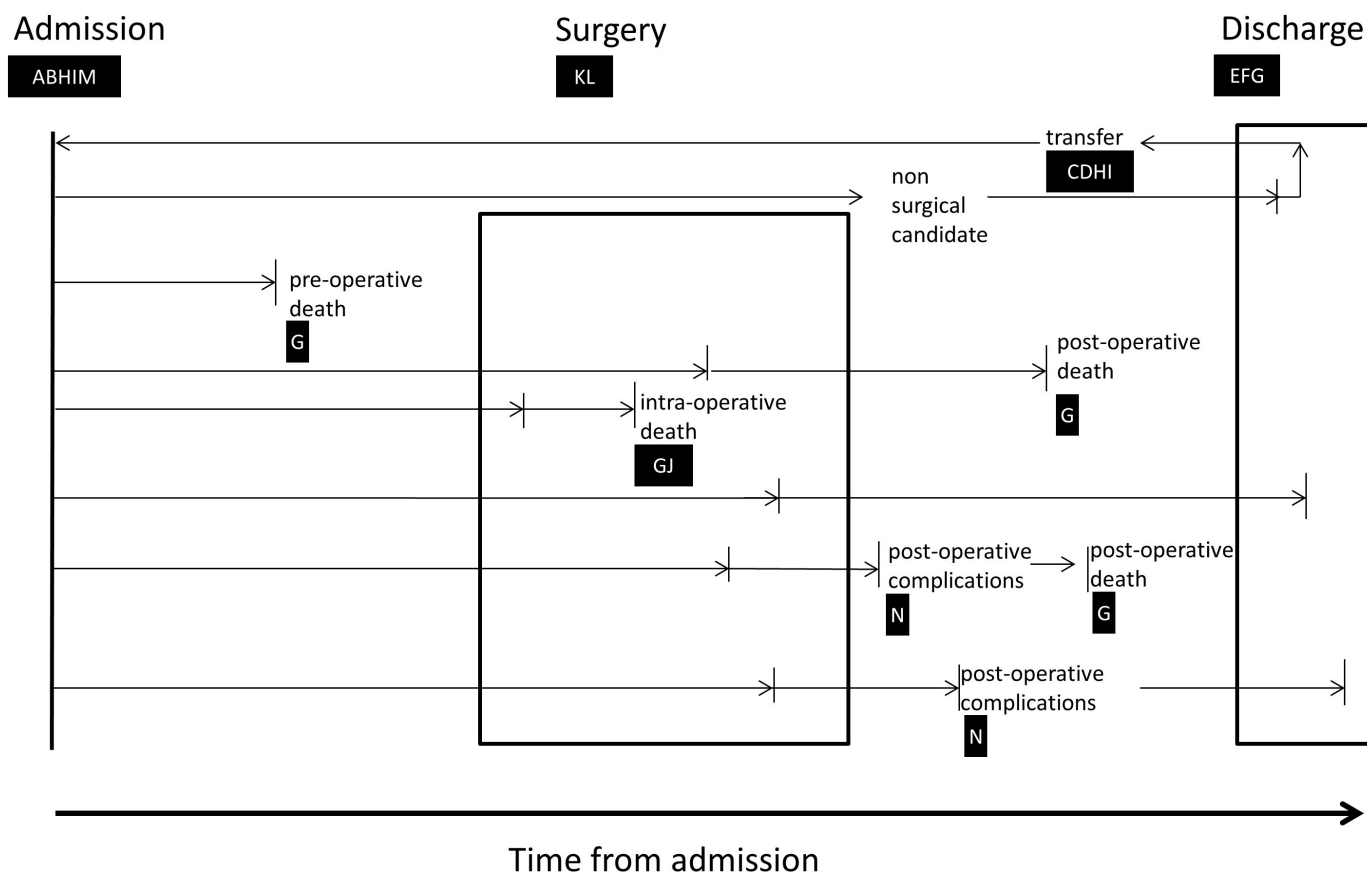
### Conceptual framework episode type 1: first abstract episode

We consider each abstract for each patient as a unique episode of care for hip fracture. The first abstract for each patient is considered the first episode of care for hip fracture and assigned the 'first abstract episode'.

### Conceptual framework episode type 2: contiguous hospitalisations episode

#### Combining discharge abstracts into care episodes

A detailed description of the conceptual framework for a contiguous care episode for studying the effects of surgical timing on outcomes after first hip fracture is described elsewhere.<sup>6</sup> Briefly, we map each care event to available data elements from the CIHI; the black boxes in figure 1 correspond to the CIHI elements identified in table 1. For patients with a single discharge abstract, we convert it to a single care episode. For patients with multiple abstracts, we combine some of them into a single-care episode by applying Rule 1 for transfers (box 1).



**Figure 1** Admission-based hip fracture episode of care. Letters 'A' to 'N' correspond to Canadian Institute for Health Information data elements used to identify each event in the care episode. These data elements are described in table 1. Reproduced with permission from *The Journal of Orthopaedic Research*, John Wiley and Sons.<sup>6</sup>

**Table 1** Canadian Institute for Health Information data elements used to construct the care episode. 'A' to 'N' correspond to items in figure 1. Reproduced with permission from *The Journal of Orthopaedic Research*, John Wiley and Sons<sup>6</sup>

Data element	Definition	Format/code
A: Admission date	Date the patient was admitted to facility	ddmmyyyy
B: Admission time	Time the patient was admitted to facility	hhmm
C: 'Institution from' ID	Institution at the start of transfer	Five-digit institution number
D: 'Institution to' ID	Institution at end of transfer	Five-digit institution number
E: Discharge date	Date of discharge from facility	ddmmyyyy
F: Discharge time	Time of discharge from facility	hhmm
G: Discharge disposition	Patient status at discharge from facility	01—transferred to inpatient hospital 02—transferred to long-term care 03—transferred to palliative care 04—discharged home with support 05—discharged home 06—discharged self 07—died
H: Diagnosis code 1 to 25	A diagnosis contributing to hospitalisation	ICD-10 code
I: Diagnosis type 1 to 25	The relationship to the hospitalisation	M—the most responsible diagnosis 1—pre-admit comorbidity diagnosis 2—post-admit comorbidity 3—secondary diagnosis 9—external cause of injury code W—diagnosis associated with first transfer X—diagnosis associated with second transfer Y—diagnosis associated with third transfer
J: Death during intervention	Patient expired during an intervention	Y—Yes
K: Intervention start date	Date when the intervention episode started	ddmmyyyy
L: Intervention code	The intervention performed	CCP or CCI code
M: Hospital peer group	The type of facility at admission	Teaching Community—small Community—medium Community—large
N*: Patient safety indicator	Serious postsurgical complications	Deep vein thrombosis/pulmonary embolism Pneumonia Sepsis Shock or cardiac arrest Gastrointestinal haemorrhage/acute ulcer

\*Derived from AHRQ PSI-4-case finding tool<sup>23</sup> ICD10, International Classification of Diseases, tenth revision; CCP, Canadian Classification of Procedure codes; CCI, Canadian Classification of Health Intervention.

After initial hospitalisation, some patients return to hospital for revision surgery, medical treatment of a complication or non-surgical patients may also return for surgery if they are no longer considered unfit for surgery (change in care). For abstracts that are not assigned by the transfer rule, we identify related episodes of revision, readmission or change in care by applying the respective *Rule 2, 3 or 4* (box 1). For patients with a new hip fracture, we construct another care episode by applying *Rule 5* (box 1). We selected 90 days as the cut point between related and new episodes of care based on the US Surgical Hip and Fracture Femur Treatment Model, which operated on a 90-day window as evaluation indicated 'significant services related to the clinical condition that is the focus of the model (hip fracture) occurred during days 31–90'.<sup>10</sup>

These patients follow different clinical care pathways and often have different clinical outcomes.<sup>11</sup>

## Operationalising conceptual framework episode type 2: contiguous hospitalisations episode

### Building the data model

We import the CIHI discharge abstracts into Oracle. We develop scripts for linking abstracts into care episodes. We link all combination of abstracts for a given patient identifier. We then remove combinations that are not sequential, and those which violate *Rule 1* (box 1). We import the remaining linked abstracts into a table 'Episode\_Abstracts' (figure 2). This table serves as the foundation for additional relational tables.

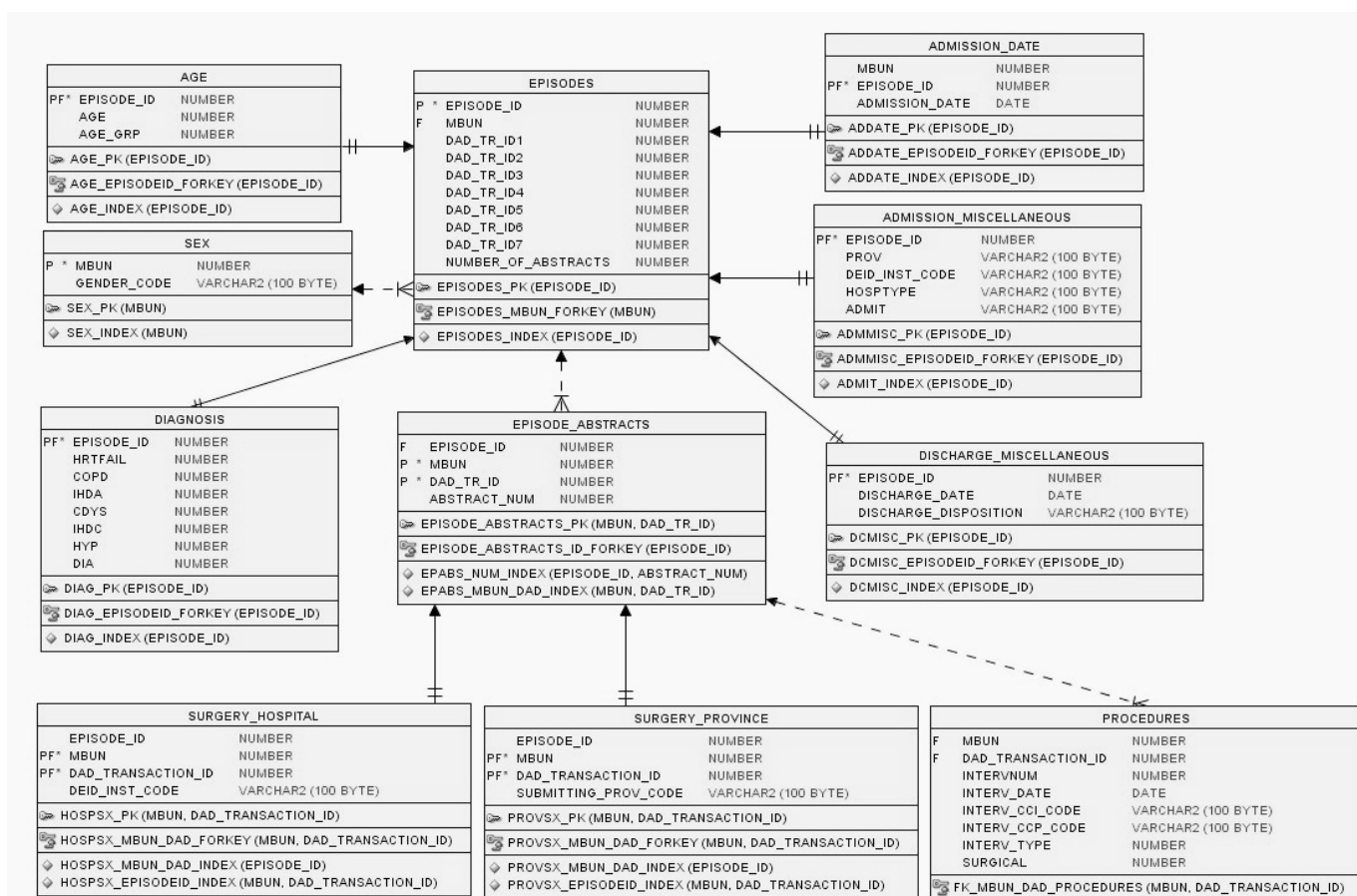


### Box 1 Rules for combining discharge abstracts into care episodes.

- **Rule 1:** Two abstracts are considered contiguous (linked by transfer) if discharge and following admission dates are the same, or 1 day apart.<sup>15</sup>
- **Rule 2:** Surgical admission for hip fracture occurring within 90 days of discharge after initial surgical hospitalisation for hip fracture is considered related to an episode of revision surgery.<sup>10</sup>
- **Rule 3:** Non-surgical admission occurring within 90 days of discharge after initial hospitalisation is considered a related episode of readmission.<sup>24</sup>
- **Rule 4:** Surgical admission for hip fracture within 30 days of admission for initial non-surgical hospitalisation for hip fracture is considered related to an episode with a change in care plan.<sup>25 26</sup>
- **Rule 5:** Admission for hip fracture occurring more than 90 days of discharge after initial hospitalisation for first hip fracture is considered an episode of initial hospitalisation for any subsequent hip fracture.<sup>9</sup>

Next, we create the relational tables in Oracle for information at the start of an episode, the scope of the services, the end of an episode and factors inherent to the patient and the treatment setting (figure 2). These tables follow the episode structure defined in the 'Episode\_Abtracts' table whereby each row reflects a care episode. We then develop scripts to import specific data elements from the CIHI data into each relational table.

We used database normalisation to organise the data in the discharge abstracts. This normalisation is a process of creating tables and relationships between tables to organise the data in accordance with the series of predefined rules.<sup>12</sup> This approach improves organisation of the data elements in the discharge abstracts, data integrity and minimises redundancy.<sup>12</sup> In order to relate the tables to one another, we flag a primary identifier in the CIHI data, a unique variable to identify each record. We insert the relevant primary identifier as a foreign variable in the other relational tables to identify a relationship.



**Figure 2** Data model to relate multiple abstracts of hip fracture care for a given patient through a series of data tables and establishing relationships between them. Tables include variables relating to patient age (AGE), sex (SEX), admission (ADMISSION\_MISCELLANEOUS), discharge (DISCHARGE\_MISCELLANEOUS), pre-admission comorbidity (DIAGNOSIS) and hospital (SURGERY\_HOSPITAL) and province (SURGERY\_PROVINCE) at surgery. Further tables represent abstracts grouped by episodes of care ID (EPISODES), abstracts ungrouped but associated with episodes of care ID (EPISODE\_ABSTRACTS) and the admission date and time for each episode of care (ADMISSION\_DATE). Dashed arrow from procedures to episode\_abstracts represents one-to-one relationship. Dashed arrow from episode\_abstracts to episodes and from episodes to sex represents many-to-one relationship. Diamond represents index - the mechanism for more efficient queries. P/key symbol represents primary identifier; unique variable for identification. F/key symbol represents foreign variable from another table to show relationship.

### Building the analytical database

We use the relational tables to update a master analytical database within Oracle. Each row represents a unique care episode. However, a patient may have more than one care episode. We organise care episodes sequentially by admission date. The earliest episode is designated the first (HF\_NO=1). The second episode's admission date is considered relative to the earliest episode's discharge date. If the two dates fall within 90 days of each other, the second episode is considered related to the first (HF\_NO=1) and the two are analysed together as a single, combined episode for the purpose of determining outcomes. If the two dates fall outside 90 days of each other, the later episode is considered a subsequent hip fracture and assigned the second (HF\_NO=2) and is not analysed with the earlier episode. The process is repeated until all episodes are assigned.

Next, we determine whether episodes are the initial hospitalisation or a related episode. We organise episodes of the first and those related to the first sequentially. We determine whether the first episode was surgical or non-surgical. We then assign a flag for revision surgery, readmission or change in care to the related episode based on the presence or absence of surgery.

Data for the identification of episode number (HF\_NO) are entered into the analytical database as a numeric column. Data for the identification of episode type (initial hospitalisation, revision, readmission or change in care) are entered into the analytical database as indicator variable columns. The analytical database is then exported as a csv file from Oracle.

### Internal validation

We completed extensive internal validation of the data model and analytical database including data type, range checks, code and cross-referencing. Two database analysts built the data model and analytical database independent of each other for structured validation of the complex processing criteria.

### Study outcome

In this study, we focus on outcomes of hospitalisation for the first hip fracture. The study outcomes were treatment type, timing of surgery (among surgically treated) and in-hospital death following the first hip fracture. We identified treatment as the occurrence of surgery for first hip fracture during a care episode from Canadian Classification of Health Intervention codes (CCI: VA74^^, IVA53^^, IVC74^^, ISQ53^^) and Canadian Classification of Procedure codes (CCP: CCP: 9054, 9114, 9134, 9351, 9359, 9361, 9362, 9363, 9364, 9369). We identified the timing of surgery from the date of admission on the first abstract of the episode and the procedure date. We define early surgery as 'on the day of or day after admission' and delayed surgery as 'two or more days after admission'.<sup>13</sup> We identified in-hospital death after first hip fracture from CIHI discharge destination codes.

### Statistical analysis

We calculate the percentage of patients with first hip fracture treated surgically, patients delayed to surgery and patients who die for (1) the first abstract episode and (2) the first contiguous hospitalisations episode from our data model. We estimate the percentage change between the two episodes using the formula:

$$\left| \frac{X_c - X_a}{X_c} \right| * 100$$

where Xc refers to the percentage for the contiguous hospitalisation episode and Xa refers to the percentage for the first abstract episode.

### Patient and public involvement

Patient and the public were not involved in this study.

## RESULTS

The sample includes 151 477 patients with a single discharge abstract, and 38 258 patients with multiple abstracts after removal of three duplicate abstracts.

### Outcomes episode 1: first abstract episode

We excluded 284 patients with post-admission hip fracture and three with open hip fracture, leaving us with 189 448 patients for analysis. Out of 189 448, 158 633 (83.7%) patients underwent surgery, of which 51 502 (32.5%) were delayed, and 10 324 (6.5%) died after surgery (table 2) and 30 815 (16.3%) patients were discharged without surgical treatment. The discharge disposition for 4 200 (13.6%) of these non-surgical patients is death (table 2, figure 3).

### Data model episode 2: contiguous hospitalisations episode

For all the 151 477 patients with a single abstract, we identified patients with episodes of initial hospitalisation. For patients with multiple abstracts we combined abstracts linked by transfer to identify patients with episodes of initial hospitalisation for first hip fracture (n=38 258). We excluded 284 patients with post-admission hip fracture and three with open hip fracture, leaving us with 189 448 patients for analysis. From the 189 448 patients with an episode of initial hospitalisation for the first hip fracture, we identified 1 611 (<1%) patients with related episodes of revision surgery, 1 876 (<1%) patients with readmission and 276 (<1%) patients with a change in care. Further, we identified episodes for a subsequent hip fracture for 11 234 (5.9%) patients.

### Outcomes episode 2: contiguous hospitalisations episode

Out of the 189 448 patients with episodes of initial hospitalisation for first hip fracture, 173 527 (91.6%) undergo surgery, of which 62 034 (35.7%) were delayed and 11 695 (6.7%) died after surgery (table 2). We found that 15 921 (8.4%) patients were discharged without surgical treatment. The discharge disposition for 4 545 (28.5%) of these non-surgical patients was death (table 2, figure 3).

**Table 2** Treatment, timing of surgery among surgically treated, and death after hip fracture based on contiguous hospitalisation episode and on first abstract approaches

	Contiguous hospitalisation episode n (%)	First abstract n (%)	Percentage change*
<b>Treatment</b>			
Non-surgical patients	15 921 (8.4)	30 815 (16.3)	94.1
Surgical patients	173 527 (91.6)	158 633 (83.7)	8.6
<b>Timing†</b>			
Not delayed to surgery	111 486 (64.2)	107 124 (67.5)	5.1
Delayed to surgery	62 034 (35.7)	51 502 (32.5)	9.0
<b>Death</b>			
Deaths after non-surgical treatment	4545 (28.5)	4200 (13.6)	52.3
Deaths after surgical treatment	11 695 (6.7)	10 324 (6.5)	3.0

\*calculated as  $|X_c - X_a / X_c| * 100$ , where  $X_c$  refers to the percentage for the contiguous hospitalisation episode and  $X_a$  refers to the percentage for the first abstract episode.

†Surgical timing was not computed for seven patients with invalid procedure date.

### Percentage change between first abstract and contiguous hospitalisations episode

The first abstract underestimates the percentage of patients surgically treated by 8.6%, delayed by 9.0% and who die by 3.0% when compared with episodes based on contiguous hospitalisations (table 2).

## DISCUSSION

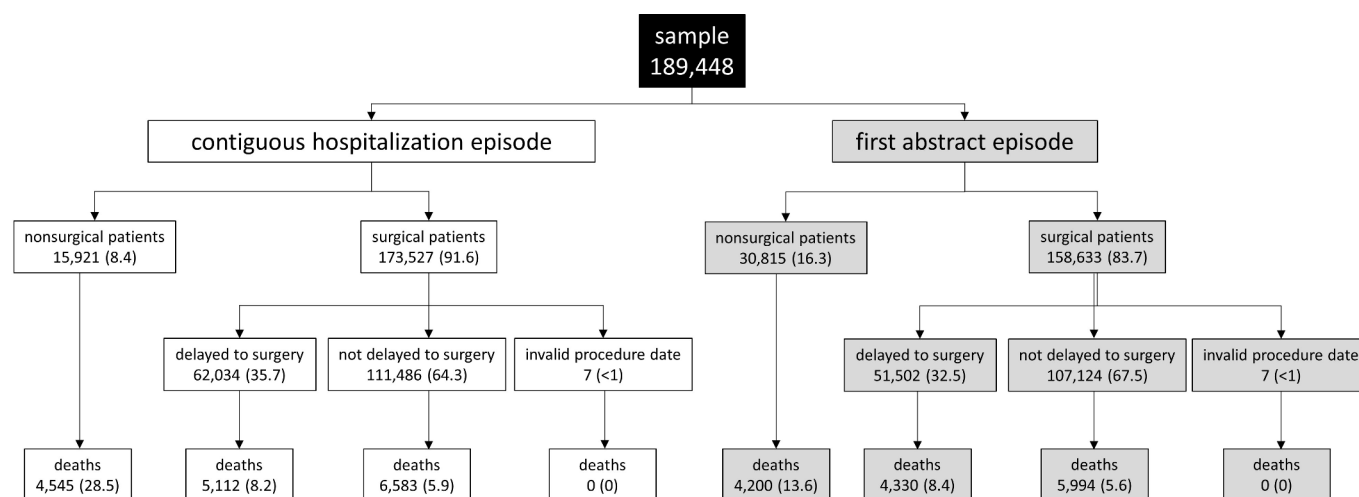
### Main findings

This paper provides an overview of the steps required to operationalise a conceptual framework for care episodes for studying the effects of timing of first hip fracture surgery on outcomes. We demonstrate that episodes based on the first abstract underestimate the percentage of patients surgically treated by 8.6%, delayed by 9.0% and who die after surgery by 3.0% when compared with episodes based on contiguous hospitalisations.

### Explanation and comparison with other studies

Researchers need to construct valid care episodes to correctly reflect the entirety of the care experience. Using our conceptual framework and data available from the CIHI, we capture pre-surgical transfers, surgery, post-surgical transfers and outcomes of admission including pre-surgical death, post-surgical complications and ensuing death, as well as events following discharge, such as readmissions, revisions and subsequent hip fractures. Using the time stamps recorded, we estimate the durations of hospital stay, pre-surgical stay and post-surgical stay. The percentage of patients admitted with hip fracture who underwent surgery, and who died in-hospital are similar to prospectively collected data.<sup>14</sup>

Fransoo *et al* failed to account for transfers results in underestimation of the duration of care episodes by up to 30% and inaccurate reporting of outcome occurrence.<sup>15</sup>



**Figure 3** Patient flow n (%) for 189 448 patients after first hip fracture for contiguous hospitalisation episode of care and first abstract episode of care constructs.



However, how transfers are defined (eg, within 1 or 2 days of initial admission) is less critical for reporting the outcome occurrence.<sup>15</sup> In the current context, transfers may occur in the episode of initial hospitalisation for first hip fracture, related episodes or an episode of initial hospitalisation for a subsequent hip fracture. Evaluation of all potential care episodes facilitates transparency in reporting of outcomes enabling decision-makers to determine which episodes work, on whom and under what circumstances.<sup>16</sup>

Failure to account for multiple discharge abstracts also introduces bias through underestimation of treatment, timing and occurrence of in-hospital death. First, the *first abstract* approach underestimates the number of surgically treated patients, which may lead to an underestimation of the surgical resources required to manage hip fracture patients. Second, the *first abstract* approach underestimates the number delayed to surgery, which may lead to continuation of scheduling practices that in fact delay two-thirds of patients. Finally, the *first abstract* approach underestimates the effect of surgery timing on death by excluding patients who die after transfer. Results may indicate no association between timing and outcomes, withdrawal of target times for hip fracture surgery and potentially more avoidable deaths. There are real-world examples of these potential biases. Siegemeth and colleagues report no influence of timing of surgery on death.<sup>17</sup> However, they indicate time began at admission to the treating site and did not account for pre-surgical transfers.<sup>17</sup> Single-site studies are particularly vulnerable to underestimating time to surgery.<sup>18–20</sup> Moreover, some studies explicitly exclude patients who require transfer before definitive care.<sup>21</sup> While studies refer to their episode construct, there is limited and often no discussion of the potential for bias induced by these constructs.

### Limitations

We used a Canadian database to operationalise a framework for episodes of care after hip fracture. Our approach allows preparing a data set for future inferential analyses including time to event analysis, competing risks, marginalised risks and quantile and interval regression. While we completed extensive internal validation, we did not externally validate the data model or analytical database. Therefore, results may not be generalisable to other settings. After application of our rules, there were 53 pairs of adjacent abstract unassigned as the admission and discharge date of one abstract was nested within the admission and discharge date of another abstract. The percentage of abstracts with missing admission, procedure and discharge dates were 0%, 0.0067% and 0.0038%, respectively. Given the small percentages, unassigned and missing data would not alter the interpretations presented here. We conceptualised the episode as one related to 'care' as we specified the care setting. Future research may examine 'disease' episodes related to hip fractures for the duration of care across all care

settings. As patients progress along a care pathway, diagnoses may change and increase in number as investigation results are received and further clinical examinations performed. This study did not investigate the extent to which each episode approach captures these changes. Further, we restricted outcome analysis to episodes for the first hip fracture. The profile of patients readmitted or admitted for a subsequent hip fracture is different and therefore these patients often follow a different care pathway with different anticipated outcomes. Indeed, we previously demonstrated excess mortality associated with second as compared with first hip fracture.<sup>11</sup> Finally, this study did not investigate the putative association between timing and death, nor did it investigate potential reasons for delay or death. Indeed, patient, process and system may delay surgery and also increase risk of death.<sup>22</sup> Future researchers may consider examining these associations while considering the episode of care construct.

### CONCLUSIONS

We demonstrate that not accounting for hospital transfers when evaluating acute care underestimates reporting of the percentage of patients treated surgically, patients delayed to surgery and patients who die. The information presented allows researchers to compare the reduction in bias relative to the increase in complexity of data curation when accounting for hospital transfers following hip fracture. The extent to which these findings apply to other complex conditions requiring transfer to specialist care centres needs further exploration.

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**Collaborators** The following are members of the Canadian Collaborative Study of Hip Fractures: Eric Bohm, Lauren Beaupre, Michael Dunbar, Donald Griesdale, Pierre Guy, Edward Harvey, Erik Hellsten, Susan Jaglal, Hans Kreder, Lisa Kuramoto, Adrian Levy, Suzanne N. Morin, Katie Jane Sheehan, Boris Sobolev, Jason M. Sutherland and James Waddell.

**Contributors** All members of the CCSHF contributed to the conception and design of the study. In addition KJS, BS, PG, MT, LK, and NB contributed to the acquisition and the analysis of data. KJS, ARL, BS, PG, MT, LK, JMS, LB, SNM and EH contributed to the interpretation of the analysis. KJS, ARL and BS drafted the manuscript. All authors critically revised the manuscript. All authors approved the final version for submission.

**Funding** This research was funded by the Canadian Institute for Health Research.

**Competing interests** The authors declare that (1) Boris Sobolev, Pierre Guy and the Collaborative have received grants from the Canadian Institutes of Health



Research related to this work. (2) Pierre Guy also receives funding from the Natural Sciences and Engineering Research Council of Canada, the Canadian Foundation for Innovation and the British Columbia Specialists Services Committee for work around hip fracture care not related to this manuscript. He has also received fees from the BC Specialists Services Committee (for a provincial quality improvement project on redesign of hip fracture care) and from Stryker Orthopedics (as a product development consultant). He is a board member and shareholder in Traumis Surgical Systems Inc. and a board member for the Canadian Orthopedic Foundation. He also serves on the speakers' bureaus of AO Trauma North America and Stryker Canada. (3) Suzanne Morin reports research grants from Amgen Canada, and from Merck, personal fees from Amgen Canada outside the submitted work.

**Patient consent** None declared.

**Provenance and peer review** Not commissioned; externally peer reviewed.

**Data sharing statement** We studied patient records that were anonymised and de-identified by a third party, the Canadian Institute for Health Information, an organisation which provides researchers access to data on Canadian residents. Data are available from the Canadian Institute for Health Information for researchers who meet the criteria for access to confidential data.

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